

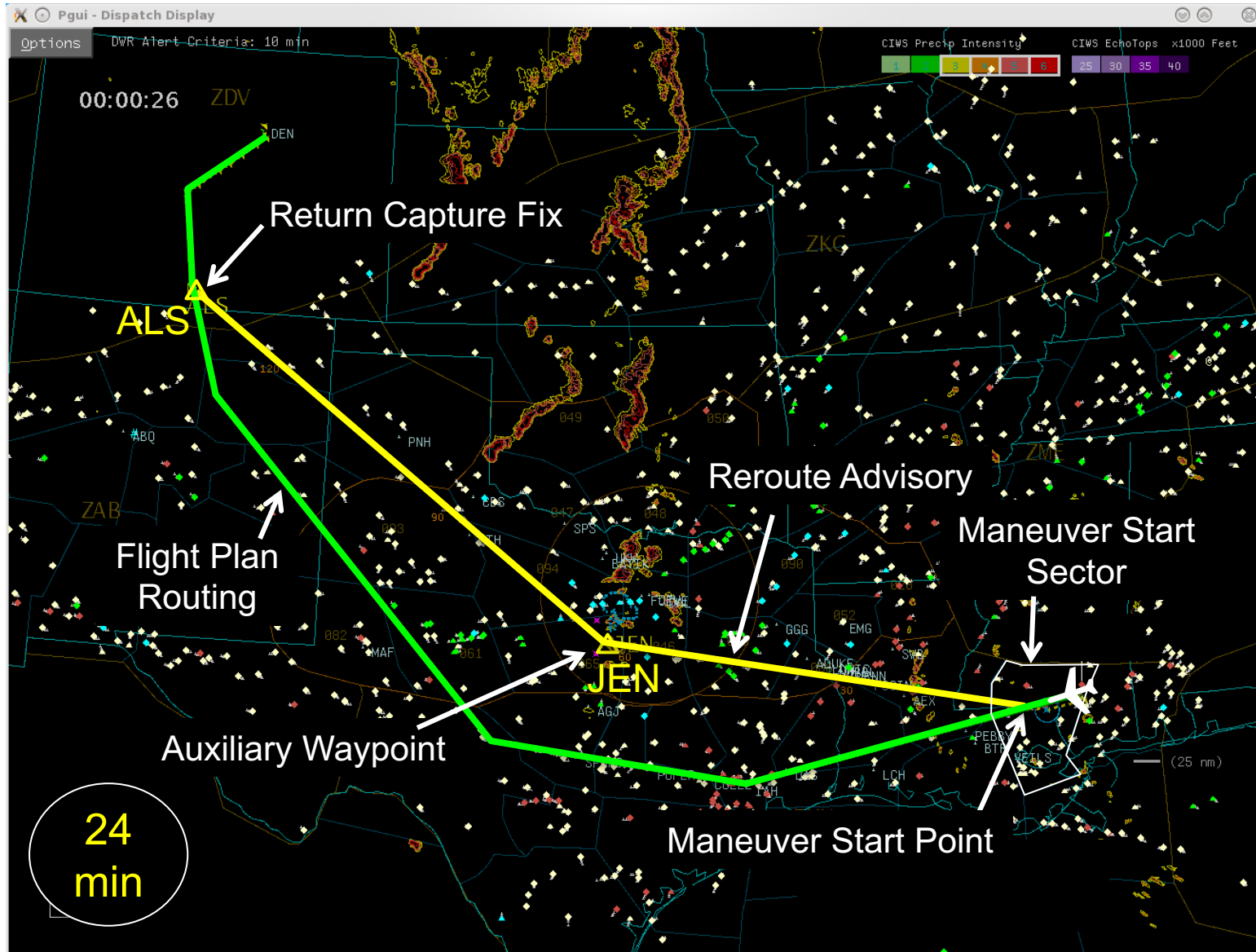


Predicting the Operational Acceptance of Route Advisories

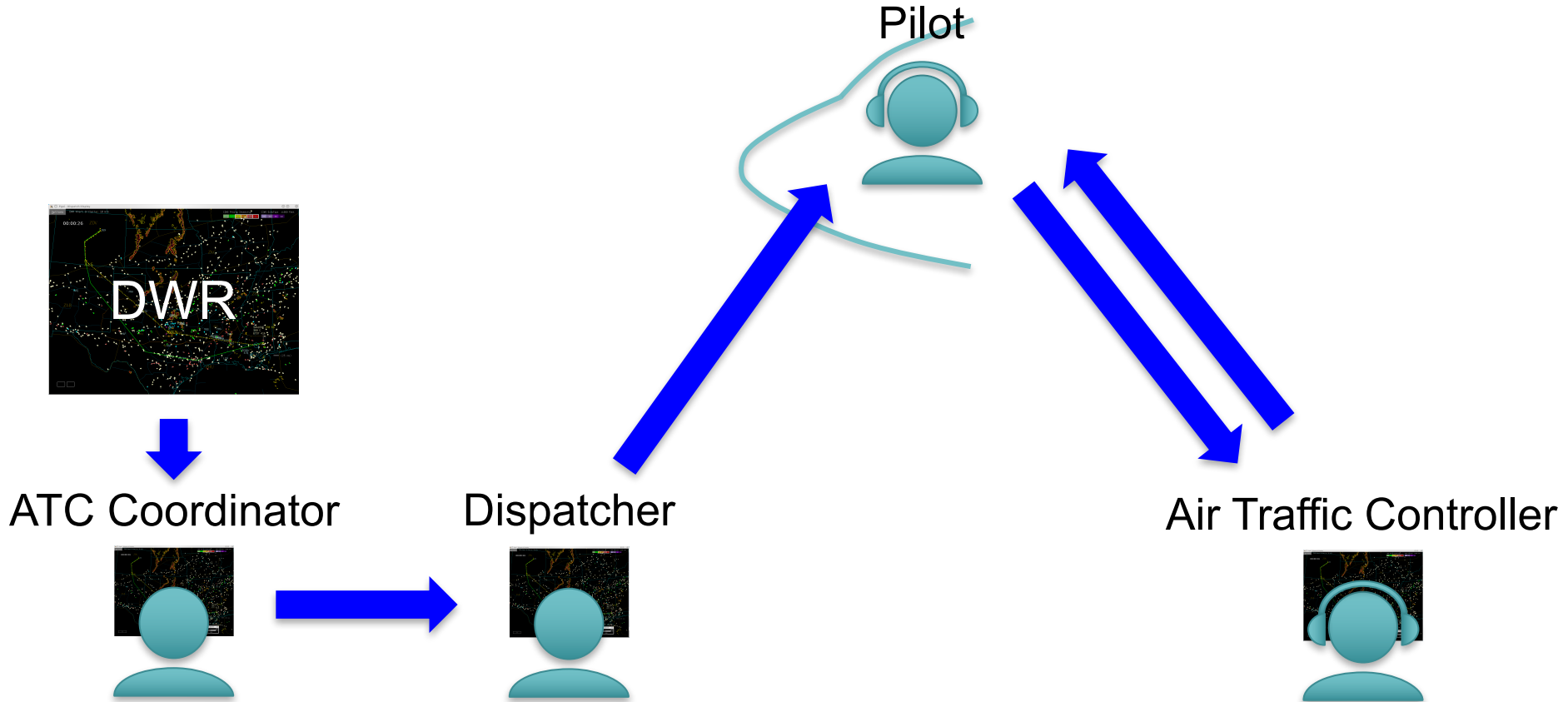
Antony Evans (Crown Consulting, Inc.)

Paul Lee (NASA Ames)

Reroute Advisories



Dynamic Weather Routes (DWR)



Motivation

		Route Observed in Flight Plan Amendment Data (Jun-Aug 2015)	
		True	False
ATC Response to DWR Route Advisory (DWR trial, 2014)	Accepted	97%	3%
	Rejected	69%	31%

Evans, et al. (2016)

- Historical usage required for ATC route acceptance
- Other factors also contribute to ATC acceptance
- Objective: Develop a predictor of operational acceptability for route advisories

Approach

Identify features

- Literature review
- Subject matter experts



Extract data

- ATC accepted routes
- ATC rejected routes



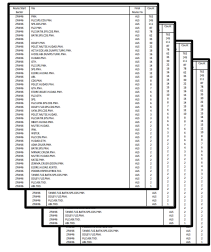
Data Mining

- Binary classifier

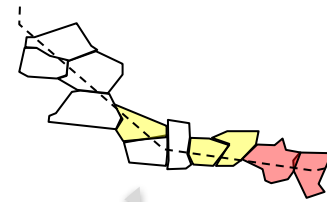


Validation

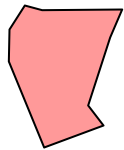
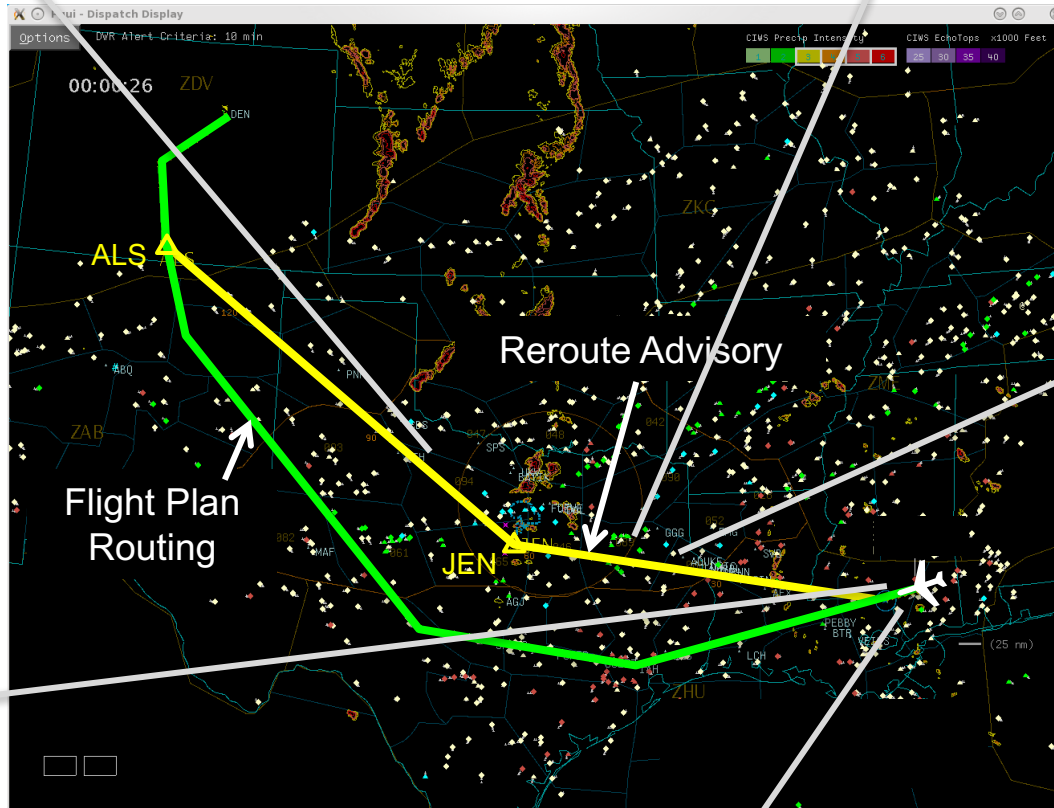
Features



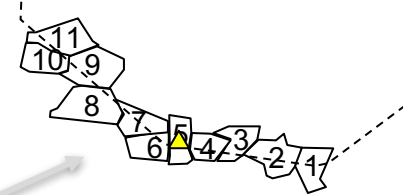
- Historical count (full route)
- Historical count (by segment)



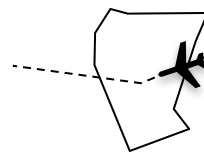
- Number sectors over capacity
- Max demand to capacity ratio



- Maneuver start sector demand/capacity
- Maneuver start sector over capacity



- Number downstream sectors
- Direct routing or via aux. waypoint



- Time to exit maneuver start sector
- Distance between maneuver start point and sector exit

Data

Usage

ASDI Data

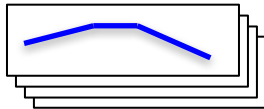
June
2015

July
2015

August
2015



Flight Plan Amendments



Common Routing Tables

Route ID	TA	Flow	Count
210001	ALB	152	152
210002	ALB	144	144
210003	ALB	111	111
210004	ALB	87	87
210005	ALB	78	78
210006	ALB	62	62
210007	ALB	54	54
210008	ALB	39	39
210009	ALB	30	30
210010	ALB	11	11
210011	ALB	18	18
210012	ALB	18	18
210013	ALB	18	18
210014	ALB	18	18
210015	ALB	18	18
210016	ALB	18	18
210017	ALB	18	18
210018	ALB	18	18
210019	ALB	18	18
210020	ALB	18	18
210021	ALB	18	18
210022	ALB	18	18
210023	ALB	18	18
210024	ALB	18	18
210025	ALB	18	18
210026	ALB	18	18
210027	ALB	18	18
210028	ALB	18	18
210029	ALB	18	18
210030	ALB	18	18
210031	ALB	18	18
210032	ALB	18	18
210033	ALB	18	18
210034	ALB	18	18
210035	ALB	18	18
210036	ALB	18	18
210037	ALB	18	18
210038	ALB	18	18
210039	ALB	18	18
210040	ALB	18	18
210041	ALB	18	18
210042	ALB	18	18
210043	ALB	18	18
210044	ALB	18	18
210045	ALB	18	18
210046	ALB	18	18
210047	ALB	18	18
210048	ALB	18	18
210049	ALB	18	18
210050	ALB	18	18
210051	ALB	18	18
210052	ALB	18	18
210053	ALB	18	18
210054	ALB	18	18
210055	ALB	18	18
210056	ALB	18	18
210057	ALB	18	18
210058	ALB	18	18
210059	ALB	18	18
210060	ALB	18	18
210061	ALB	18	18
210062	ALB	18	18
210063	ALB	18	18
210064	ALB	18	18
210065	ALB	18	18
210066	ALB	18	18
210067	ALB	18	18
210068	ALB	18	18
210069	ALB	18	18
210070	ALB	18	18
210071	ALB	18	18
210072	ALB	18	18
210073	ALB	18	18
210074	ALB	18	18
210075	ALB	18	18
210076	ALB	18	18
210077	ALB	18	18
210078	ALB	18	18
210079	ALB	18	18
210080	ALB	18	18
210081	ALB	18	18
210082	ALB	18	18
210083	ALB	18	18
210084	ALB	18	18
210085	ALB	18	18
210086	ALB	18	18
210087	ALB	18	18
210088	ALB	18	18
210089	ALB	18	18
210090	ALB	18	18
210091	ALB	18	18
210092	ALB	18	18
210093	ALB	18	18
210094	ALB	18	18
210095	ALB	18	18
210096	ALB	18	18
210097	ALB	18	18
210098	ALB	18	18
210099	ALB	18	18
210100	ALB	18	18



Usage

Feature Extraction

DWR Trial Data (ZFW and adjacent Centers)

May
2014

June
2014

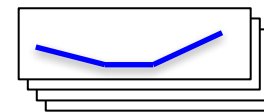
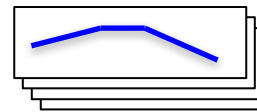
July
2014

August
2014

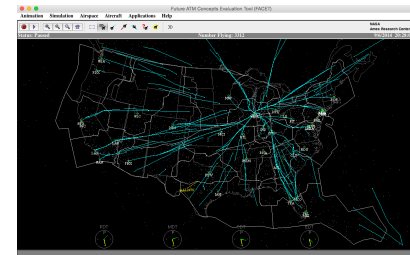
September
2014



DWR Advisories Flight Plan Amendments

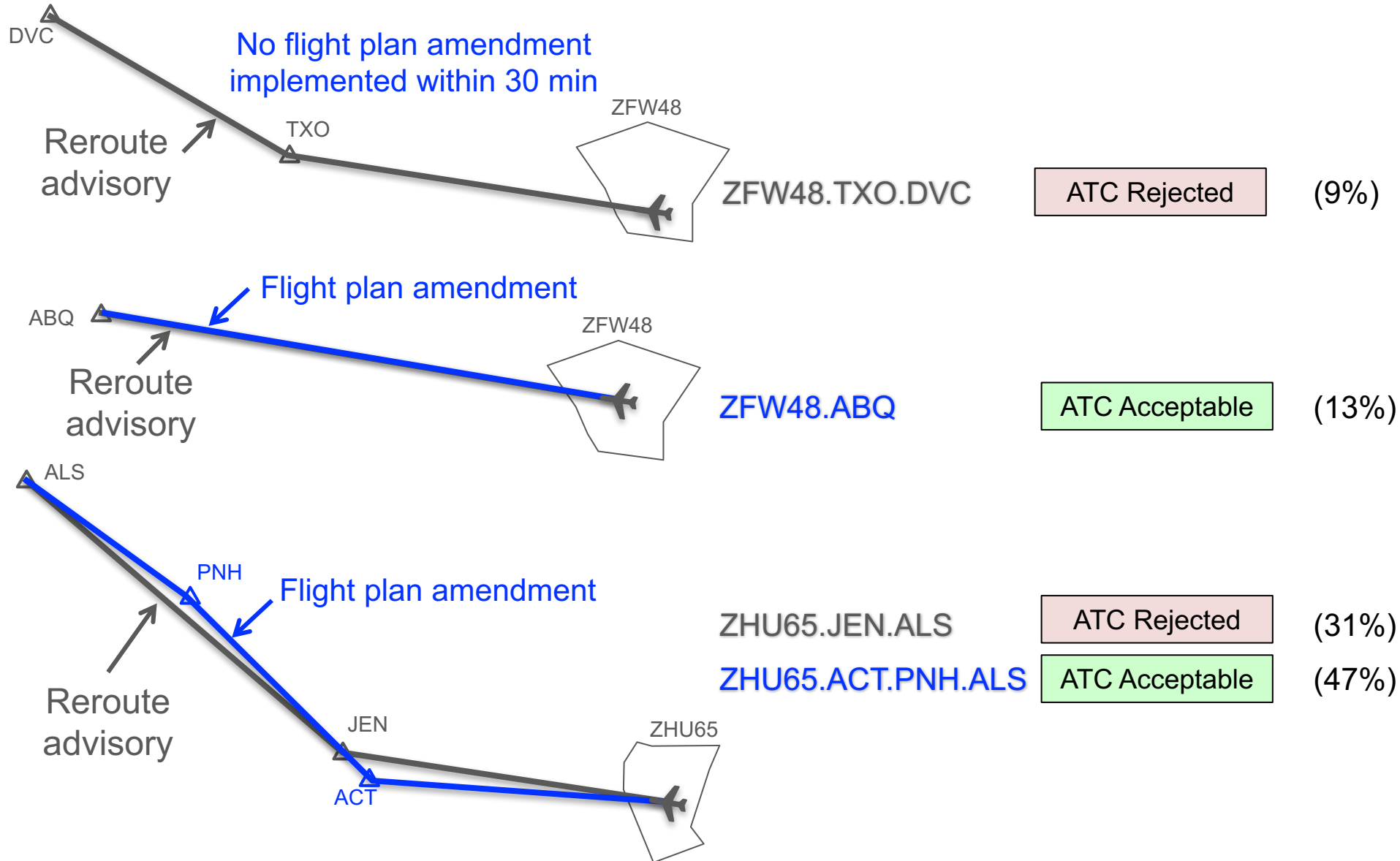


Future ATM Concepts Evaluation Tool (FACET)

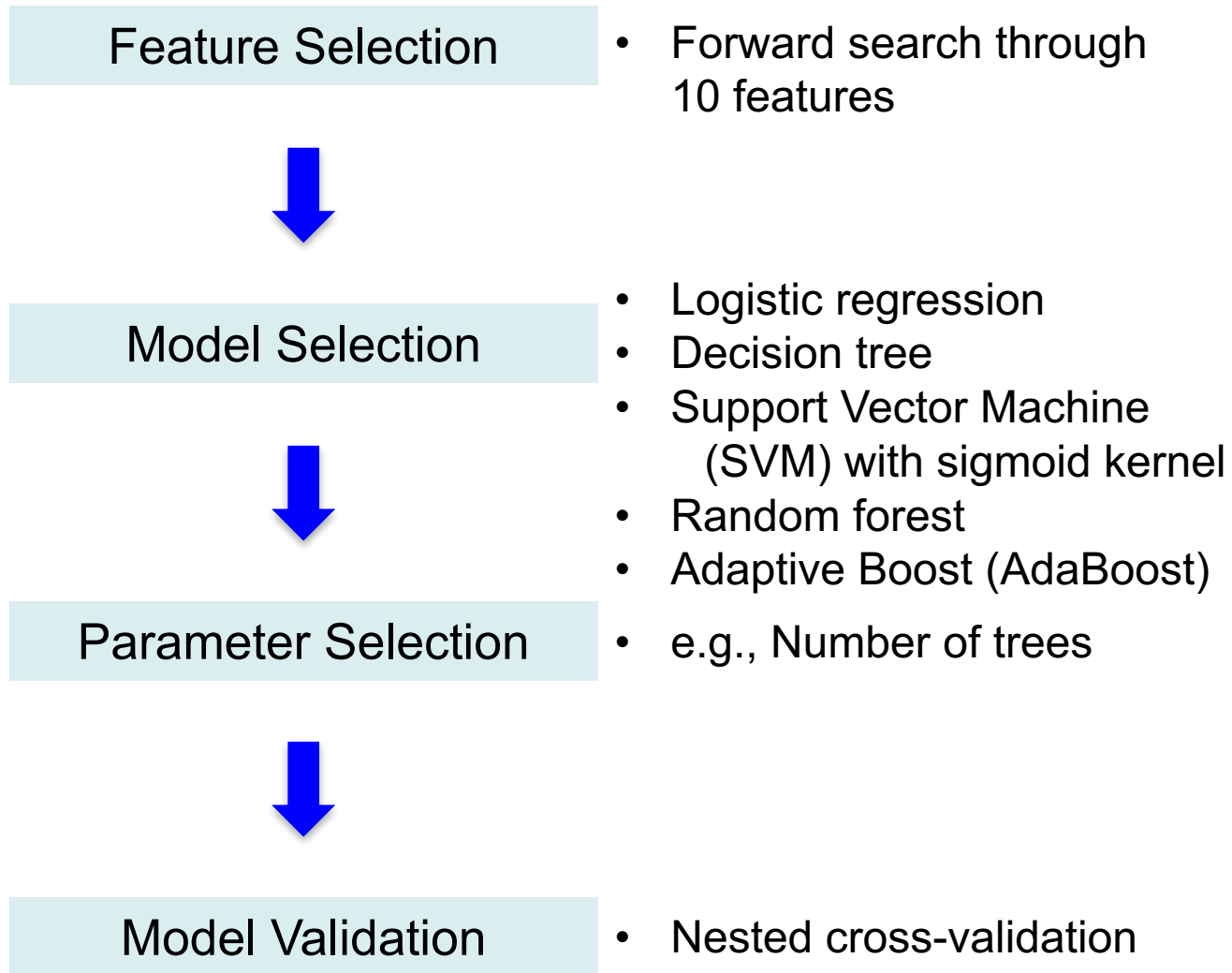


Sector Counts etc.

Classifying Routings

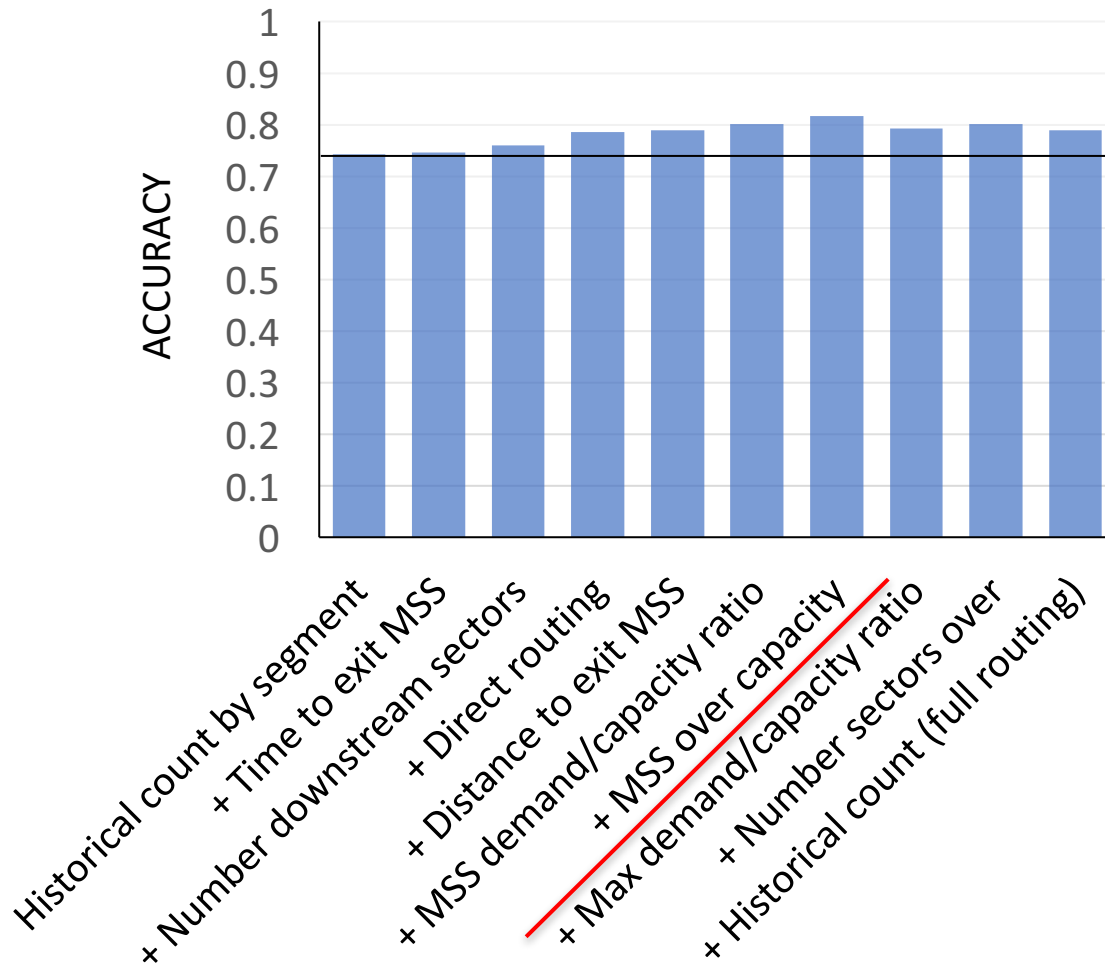


Model Development



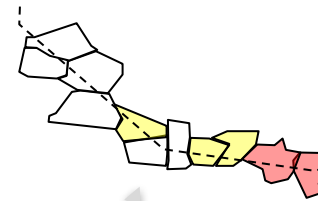
Feature Selection

- Forward Search with Random Forest, 10-fold cross validation
- 317 to 544 observations – 40% to 48% Rejected; 60% to 52% Accepted

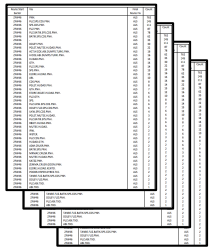


MSS – Maneuver Start Sector

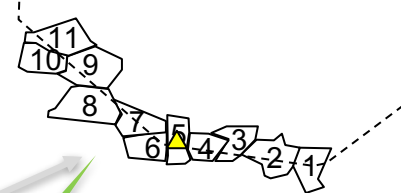
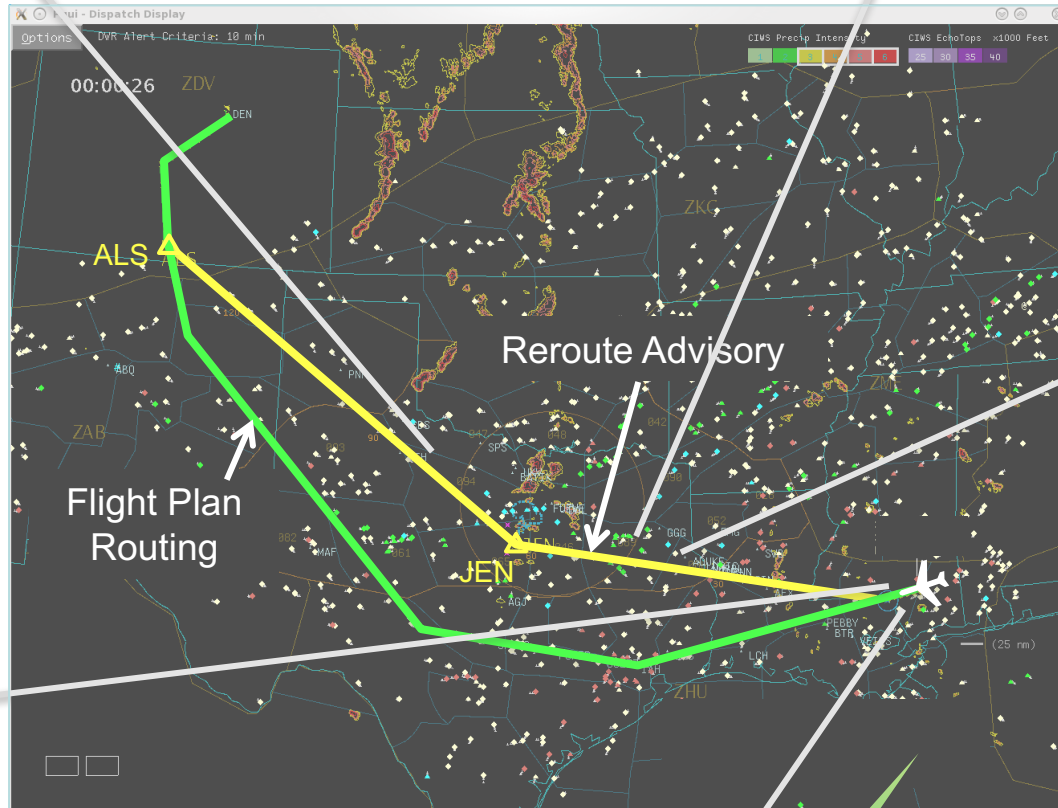
Features



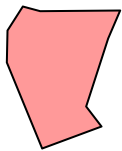
- Number sectors over capacity
- Max demand to capacity ratio



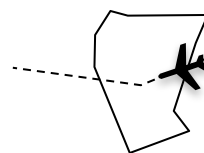
- Historical count (full route)
- Historical count (route segment)



- Number downstream sectors
- Direct routing or via aux. waypoint



- Maneuver start sector demand/capacity
- Maneuver start sector over capacity



- Time to exit maneuver start sector
- Distance between maneuver start point and sector exit

Model Selection

- 7 features
- 10-fold cross validation
- 317 observations – 48% Rejected; 52% Accepted



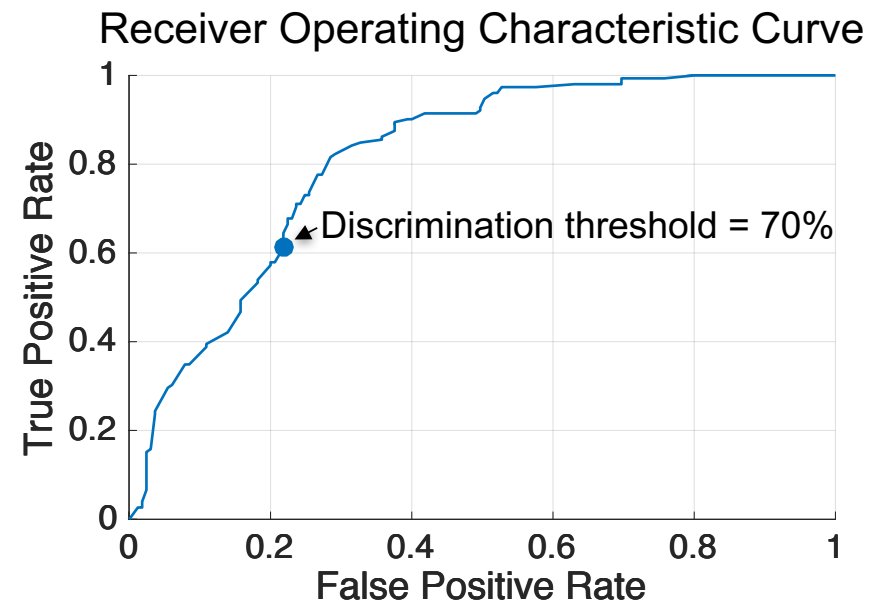
- Parameter Selection: 40 trees

Model Validation

- 7 features, Random Forest, 40 trees
- Nested 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

		Predicted	
		Rejected	Accepted
Observed (Actual)	Rejected	61%	39%
	Accepted	22%	78%

Model Accuracy: 70%



Conclusions

- Developed a predictor of operational acceptability for route advisories:
 - Accuracy of 74%
 - Route rejection predicted at rate of 88%
- Relevant model features:
 - Historical usage
 - Timing/location of request in maneuver start sector
 - Number of downstream sectors
 - Direct routing or via auxiliary waypoints
 - Demand to capacity levels in maneuver start sector
- Best performing model is Random Forest with 40 trees

Future Work

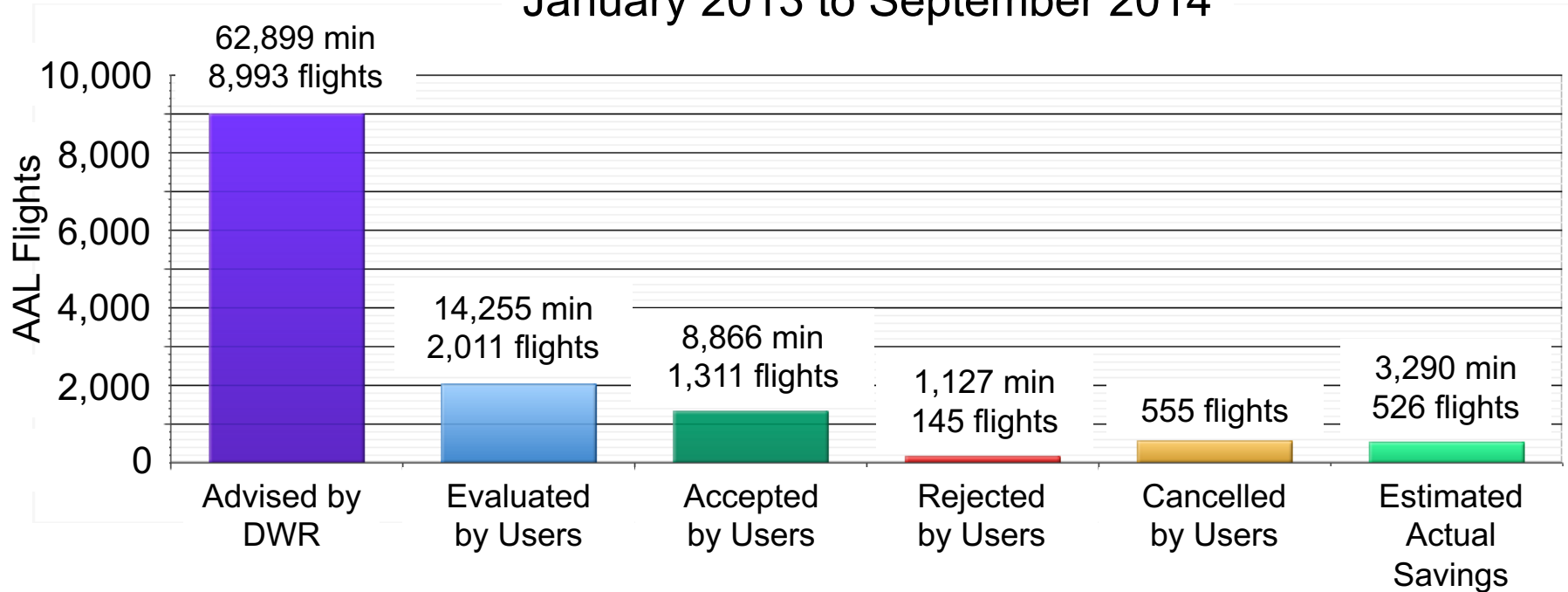
- Extension to other airspace
 - Trial data for NAS Constraint Evaluation and Notification Tool (NASCENT)
- Improve features
 - Include weather impact on maneuver start sector capacity
 - Add other features, e.g., Center information
 - May use voice recordings to identify timing and details of pilot requests to ATC

Questions?

Back-up Slides

DWR Use and Estimated Actual Savings

January 2013 to September 2014



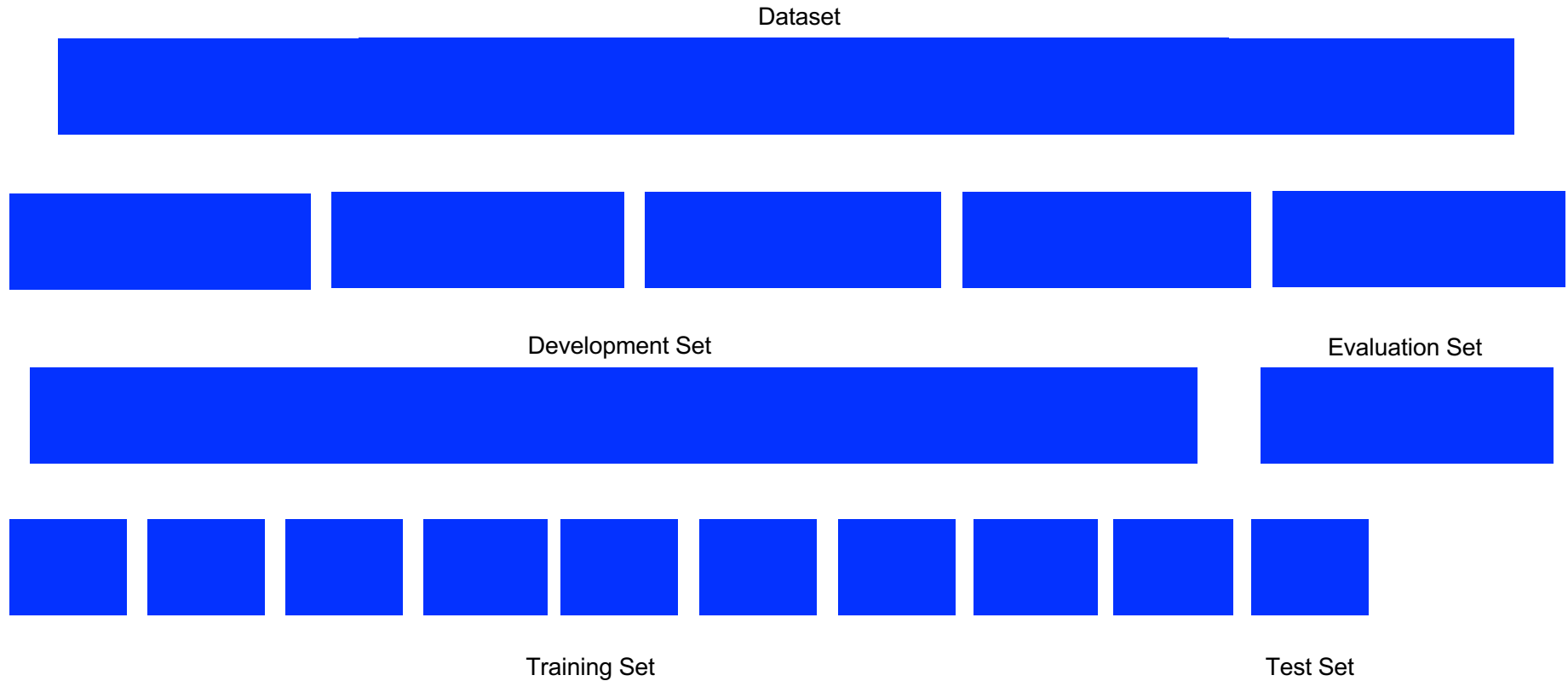
40% of dispatcher accepted routes see actual savings

McNally, D., Sheth, K., Gong, C., Sterenchuk, M., Sahlman, S., Hinton, S., Lee, C., Shih, F-T., "Dynamic Weather Routes: Two Years of Operational Testing at American Airlines," *Air Traffic Control Quarterly*, Vol. 23, No. 1, pp. 55-81, 2015.

Traditional Model Development



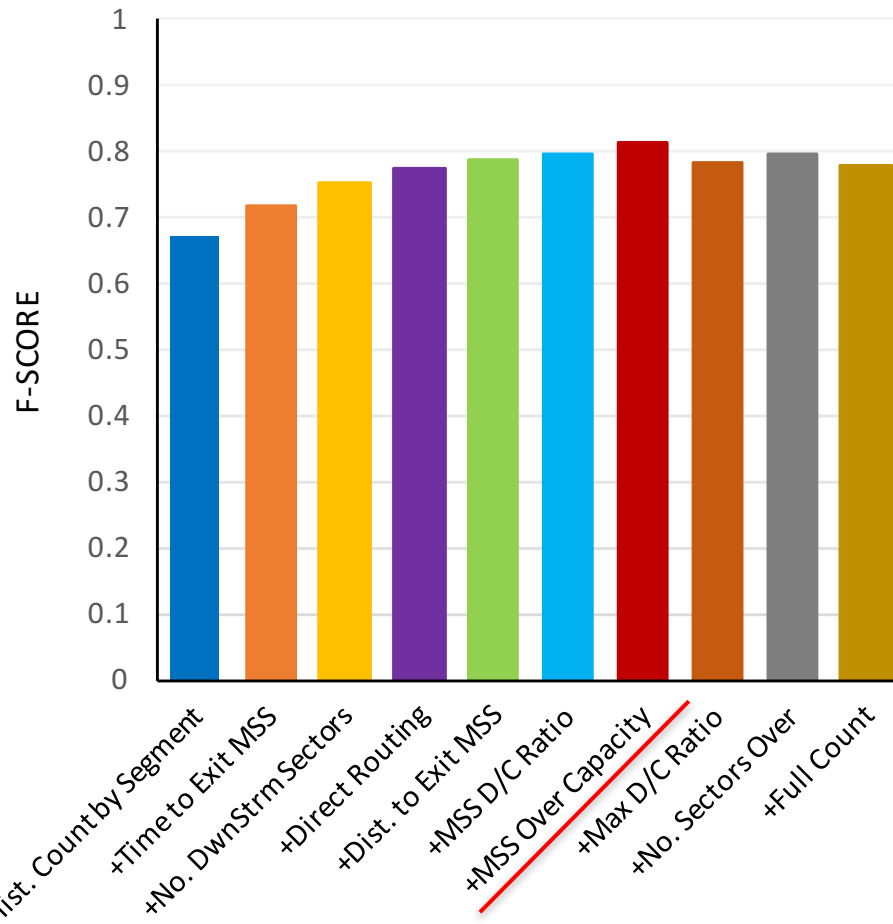
Nested Cross Validation



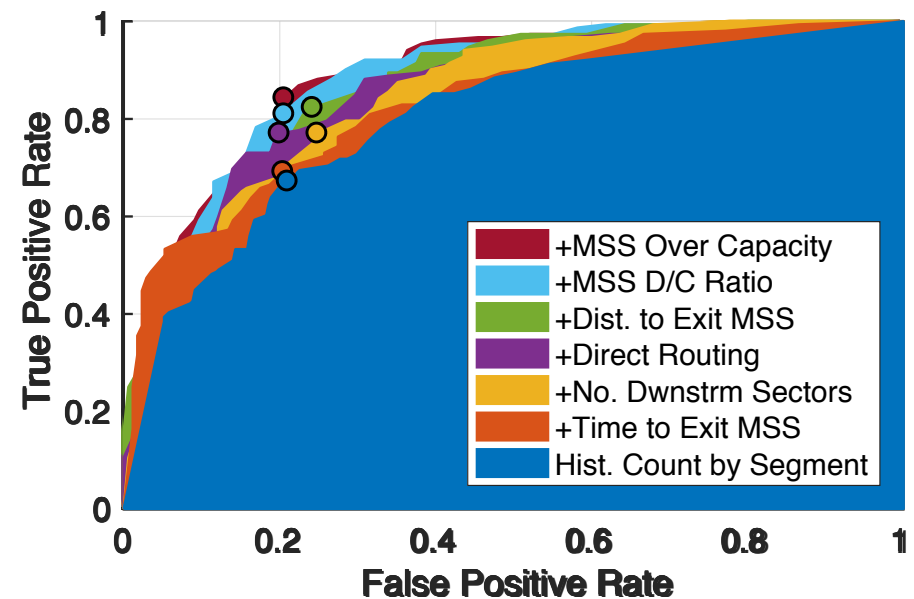
Feature Selection: Forward Search

- Random Forest, 10-fold cross validation
- 317 to 544 observations – 40% to 48% Rejected (positive); 60% to 52% Accepted (negative)

F-Score (50% discrimination threshold)



Receiver Operating Characteristic (ROC) Curve



Feature Selection: Forward Search

- Method: Random Forest, 40 trees, 10-fold cross-validation
- Positive (Rejected or Modified) 40%; Negative (Accepted) 60%
- Observations: between 317 and 544, depending on features included

Model F-Score

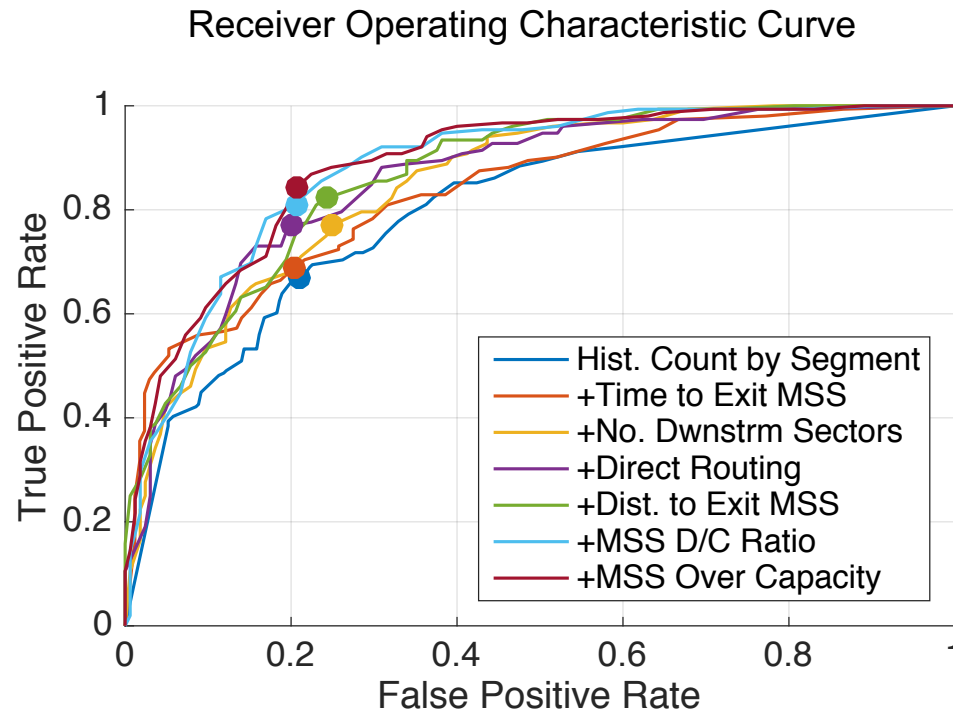
	1 Feature	2 Features*	3 Features*	4 Features*	5 Features*	6 Features*	7 Features*	8 Features*	9 Features*	10 Features*
Full Count	0.648	0.695	0.753	0.771	0.764	0.766	0.801	0.775	0.767	0.780
Concat. Count	0.674	-	-	-	-	-	-	-	-	-
Direct Routing	0.387	0.597	0.705	0.775	-	-	-	-	-	-
No. Sectors Over	NA	0.599	0.693	0.743	0.746	0.766	0.809	0.783	0.797	-
Max D/C Ratio	0.255	0.664	0.751	0.773	0.769	0.789	0.772	0.784	-	-
MSS Over Capacity	NA	0.583	0.674	0.744	0.758	0.782	0.815	-	-	-
MSS D/C Ratio	0.381	0.660	0.749	0.758	0.773	0.796	-	-	-	-
No. Dwnstrm. Sectors	0.484	0.667	0.755	-	-	-	-	-	-	-
Time to Exit MSS	0.497	0.719	-	-	-	-	-	-	-	-
Dist. to Exit MSS	0.467	0.665	0.719	0.761	0.789	-	-	-	-	-

* Includes feature set with highest F-Score from previous column

- Feature Set with highest F-Score:
 - Concatenation Count,
 - Number of Downstream Sectors,
 - Distance to Exit MSS,
 - MSS Over Capacity
 - Time to Exit MSS,
 - Direct Routing
 - MSS Demand/Capacity Ratio

Feature Selection

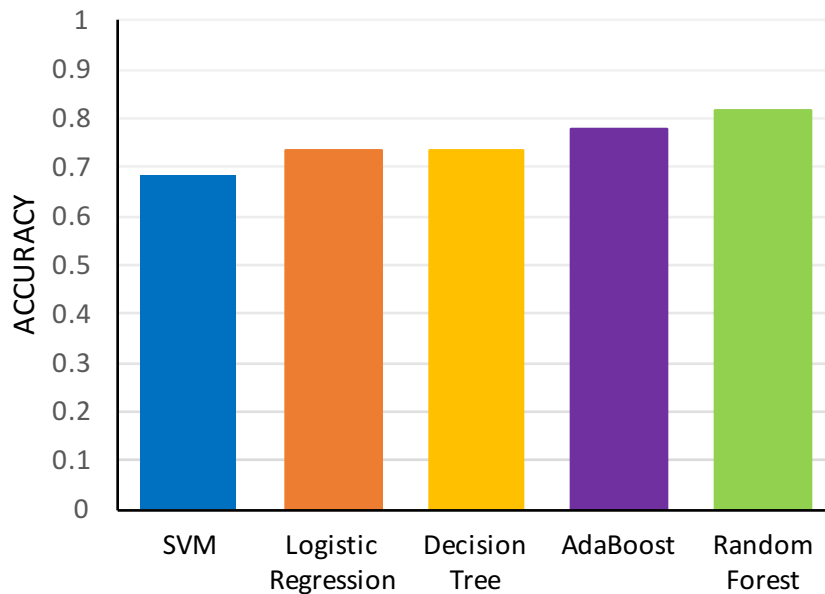
- Forward Search, using a Random Forest and 10-fold cross-validation
- Feature Set with highest F-Score:
 - Hist. Count by Segment,
 - Number of Downstream Sectors,
 - Distance to Exit Maneuver Start Sector,
 - Maneuver Start Sector Over Capacity.
 - Time to Exit Maneuver Start Sector,
 - Direct Routing,
 - Maneuver Start Sector Demand/Capacity Ratio,



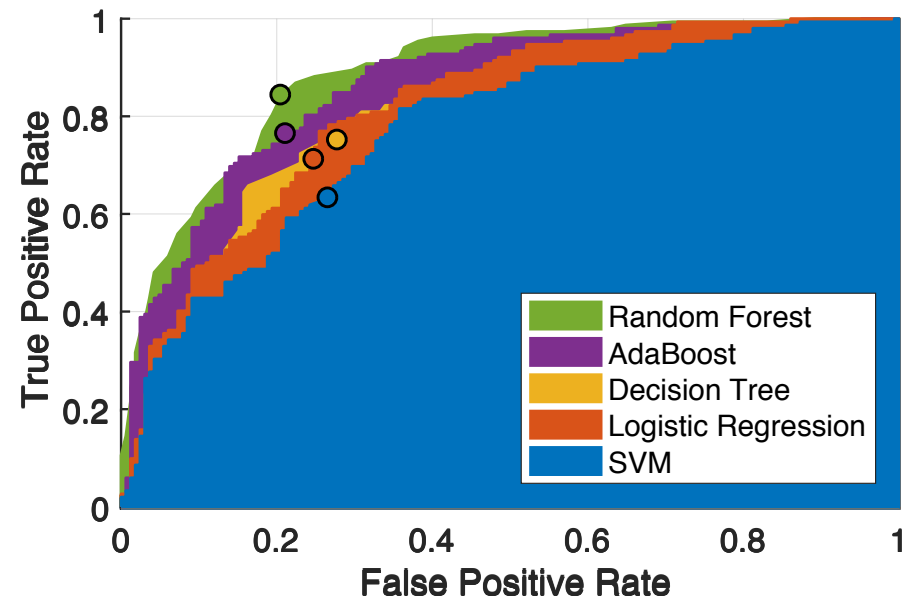
Model Selection

- 7 features
- 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

Accuracy (50% discrimination threshold)



Receiver Operating Characteristic (ROC) Curve

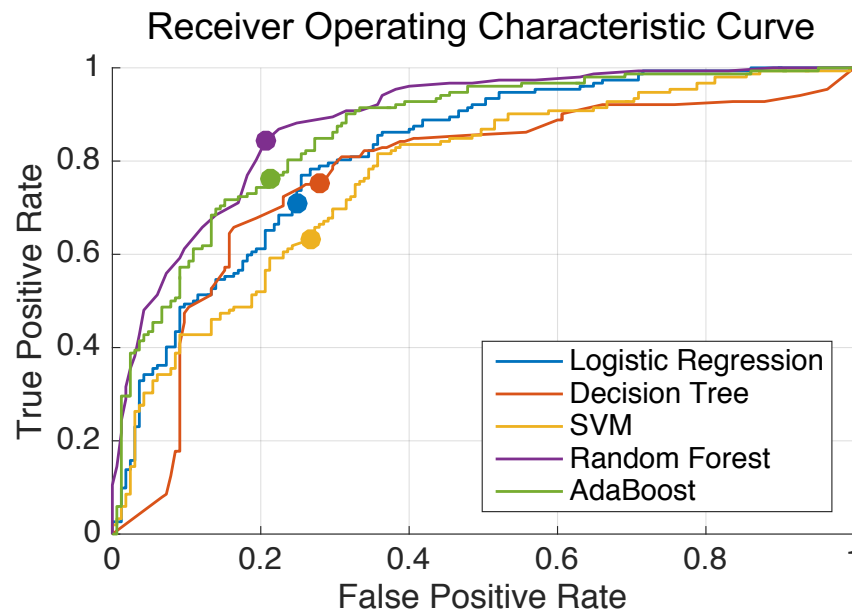


- Parameter Selection: 40 trees

Model Selection

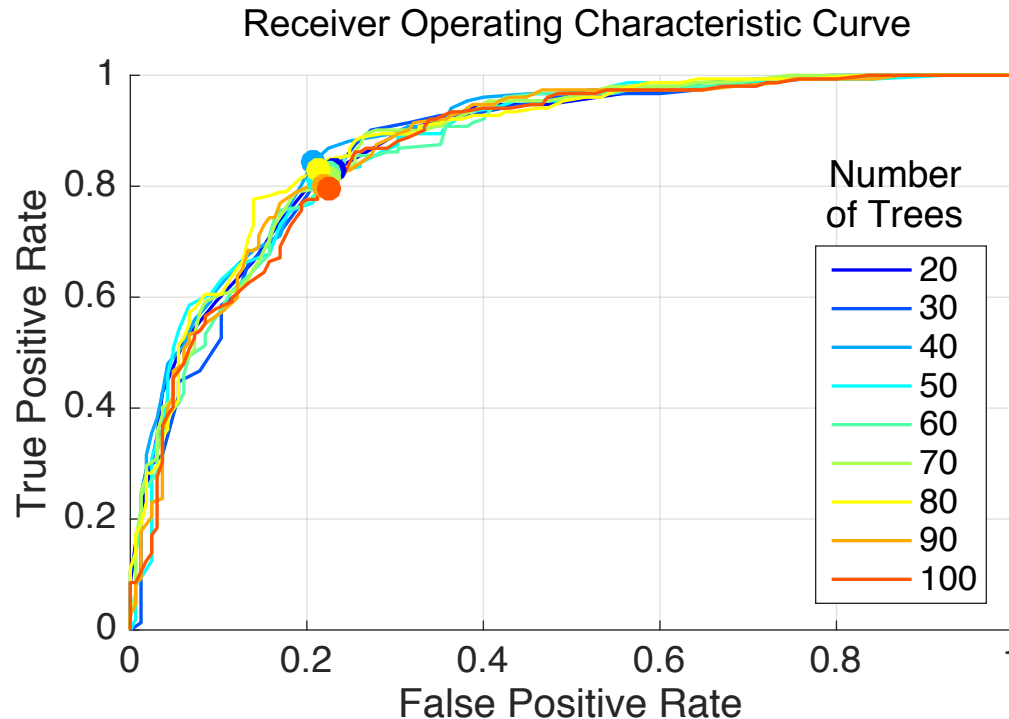
- 10-fold cross-validation
- 317 observations – 48% Positive (Rejected or Modified); 52% Negative (Accepted)

	Logistic Regression	Decision Tree	SVM	Random Forest	AdaBoost
Accuracy	0.73	0.74	0.69	0.82	0.78
Misclassification Error	0.27	0.26	0.31	0.18	0.22
True Positive Rate/Recall	0.71	0.75	0.63	0.84	0.76
True Negative Rate	0.75	0.72	0.73	0.79	0.79
Precision	0.73	0.71	0.69	0.79	0.77
F-score	0.72	0.73	0.66	0.82	0.77



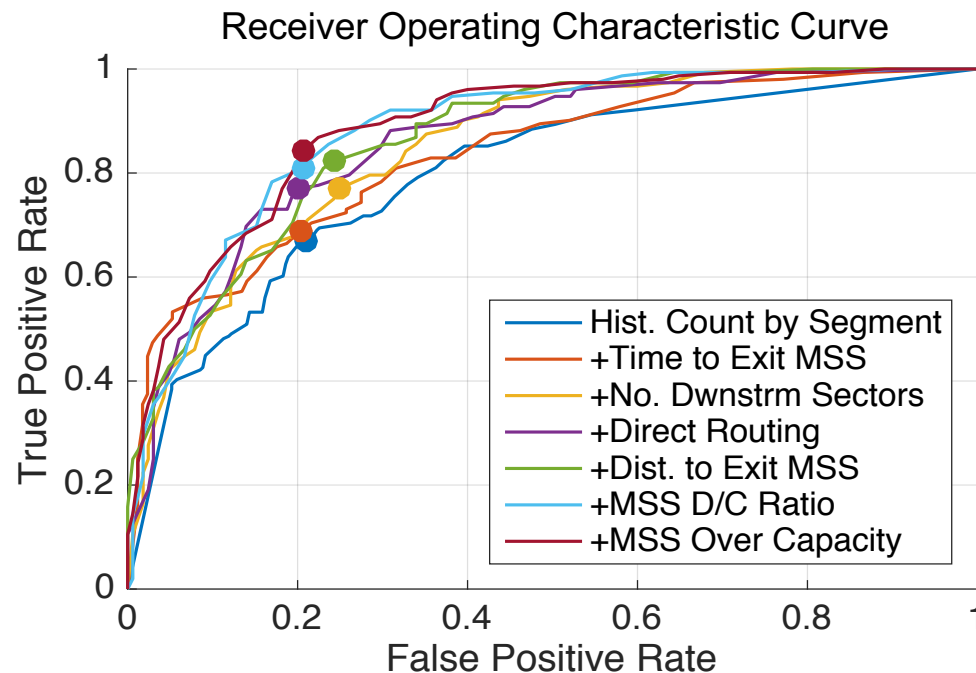
Parameter Selection: Number of Weak Learners

- Random Forest, with 10-fold cross validation
- 317 observations – 48% Positive (Rejected or Modified); 52% Negative (Accepted)
- Parameter value with highest F-Score: 40 trees



Feature Selection

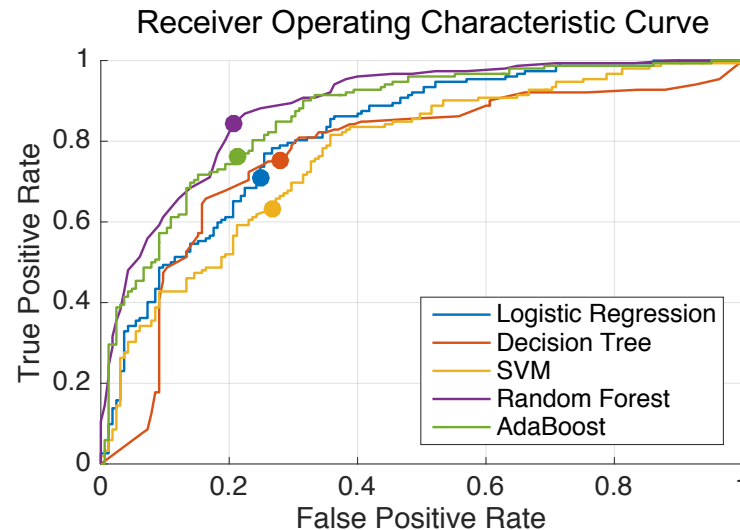
- Method: Forward Search, training a Random Forest with 40 trees, using 10-fold cross-validation
- Metric: F-Score
- Observations: between 317 and 544, depending on features included
- Data Balancing: Positive (Rejected or Modified) 40%; Negative (Accepted) 60%
- Feature Set with highest F-Score (0.815):
 - Hist. Count by Segment,
 - Number of Downstream Sectors,
 - Distance to Exit MSS,
 - MSS Over Capacity
 - Time to Exit MSS,
 - Direct Routing
 - MSS Demand/Capacity Ratio



Model Selection

- Method: 10-fold cross-validation
- Observations: 317
- Data Balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%
- Features: Hist. Count by Segment, Time to Exit MSS, No. Downstream. Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.

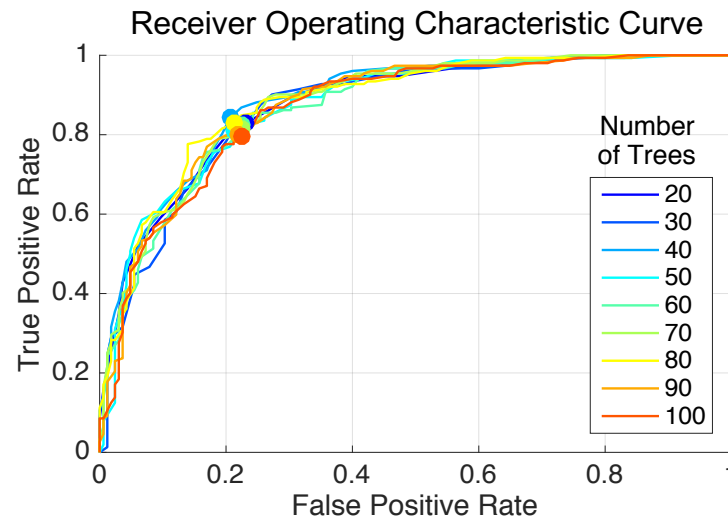
	Logistic Regression	Decision Tree	SVM	Random Forest	AdaBoost
Accuracy	0.732	0.735	0.685	0.817	0.776
Misclassification Error	0.268	0.265	0.315	0.183	0.224
True Positive Rate	0.711	0.750	0.632	0.842	0.763
True Negative Rate	0.752	0.721	0.733	0.794	0.788
Precision	0.725	0.713	0.686	0.790	0.768
F-score	0.718	0.731	0.658	0.815	0.766
Area Under ROC	0.818	0.767	0.770	0.886	0.864
Average Precision	0.776	0.687	0.735	0.870	0.826



Parameter Selection: Number of Weak Learners

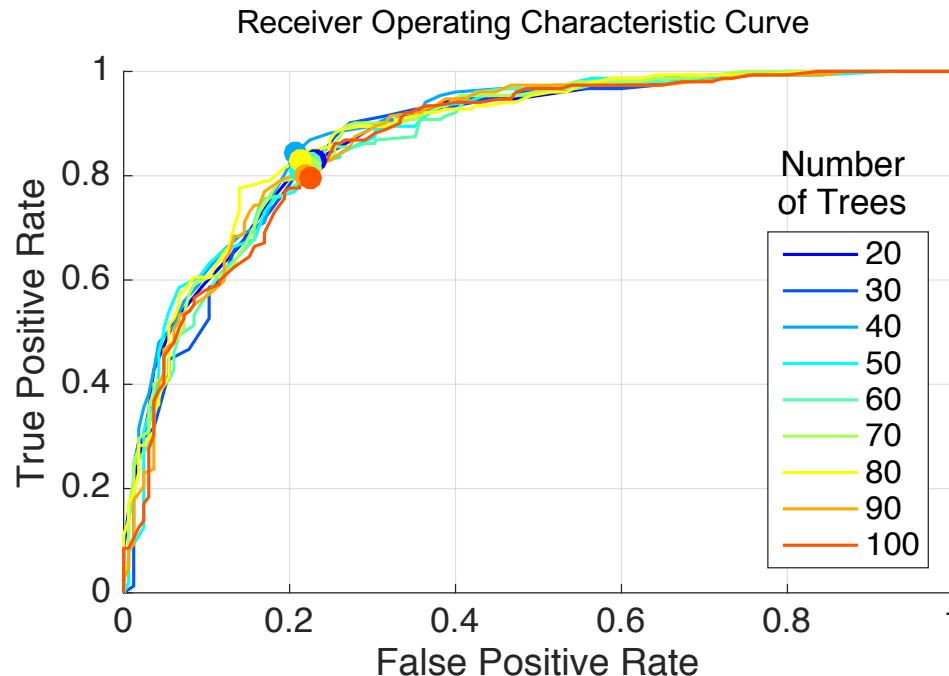
- Method: Random Forest, with 10-fold cross validation Metric: F-Score
- Data Balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52% Observations: 317
- Features: Hist. Count By Segment, Time to Exit MSS, No. Dwnstrm. Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.

Number of Trees:	20	30	40	50	60	70	80	90	100
Accuracy	0.798	0.801	0.817	0.798	0.798	0.795	0.808	0.792	0.785
Misclassification Error	0.202	0.199	0.183	0.202	0.202	0.205	0.192	0.208	0.215
True Positive Rate	0.829	0.816	0.842	0.809	0.822	0.816	0.829	0.803	0.796
True Negative Rate	0.770	0.788	0.794	0.788	0.776	0.776	0.788	0.782	0.776
Precision	0.768	0.780	0.790	0.778	0.772	0.770	0.783	0.772	0.766
F-score	0.797	0.797	0.815	0.794	0.796	0.792	0.805	0.787	0.781
Area Under ROC	0.877	0.871	0.886	0.875	0.870	0.878	0.883	0.874	0.867
Average Precision	0.860	0.820	0.870	0.833	0.844	0.854	0.863	0.840	0.835



Parameter Selection: Number of Weak Learners

- Method: Random Forest, with 10-fold cross validation
- Metric: F-Score
- Observations: 317
- Data Balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%
- Features: Hist. Count by Segment, Time to Exit MSS, No. Downstream Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.
- Parameter value with highest F-Score (0.815):
 - 40 trees

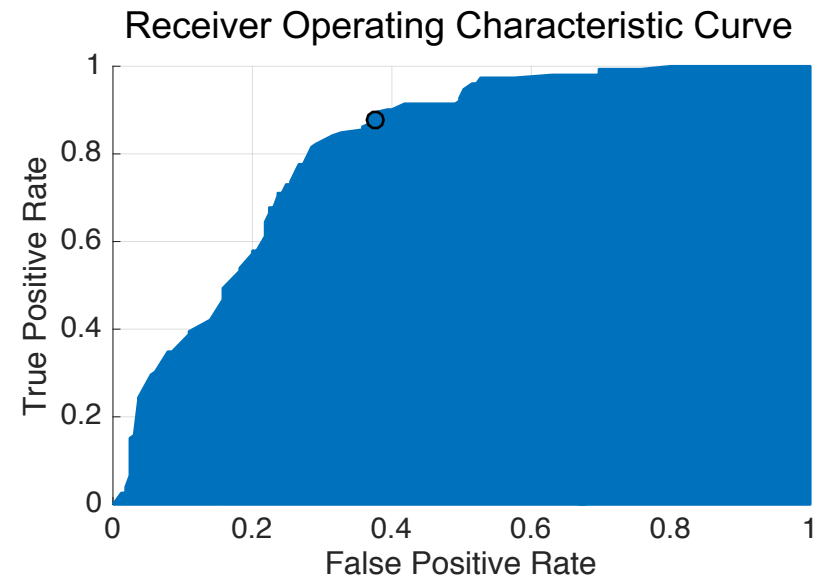


Model Validation

- Random Forest, 7 features, 40 trees
- Nested 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

		Predicted	
		Rejected	Accepted
Observed (Actual)	Rejected	88%	12%
	Accepted	38%	62%

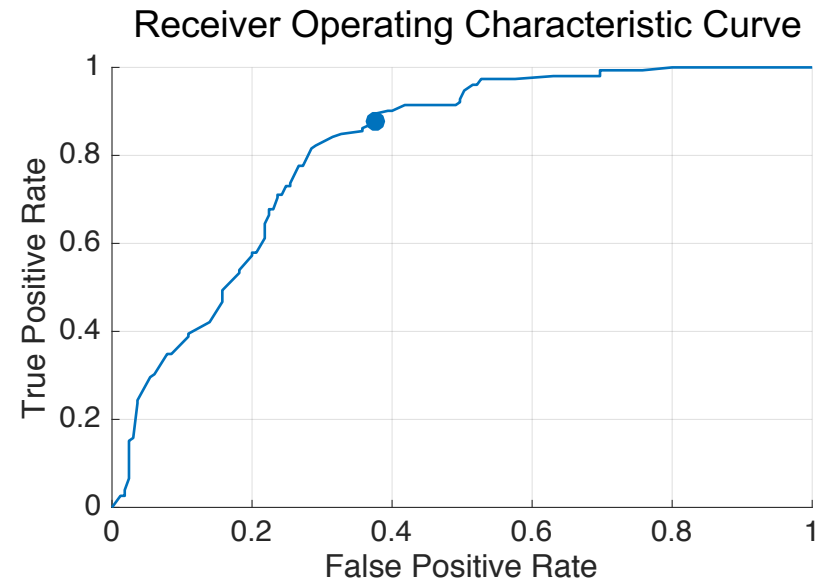
Model Accuracy: 74%



Model Validation

- Method: Random Forest, with 10-fold nested cross validation
- Observations: 317
- Data Balancing: Positive (Rejected or Modified) 40%; Negative (Accepted) 60%

	Nested Cross-Validation
Accuracy	0.744
Misclassification Error	0.256
True Positive Rate/Recall	0.875
True Negative Rate	0.624
Precision	0.682
FScore	0.767
Area Under ROC	0.814
Average Precision	0.742



Comparison to One-Class Classification

- Method: 10-fold cross-validation
- Observations: 317
- Data balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%
- Features: Hist. Count by Segment, Time to Exit MSS, No. Downstream Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Capacity

	Random Forest	Two-Class SVM	One-Class SVM
Accuracy	0.817	0.685	0.558
Misclassification Error	0.183	0.315	0.442
True Positive Rate/Recall	0.842	0.632	0.211
True Negative Rate	0.794	0.733	0.879
Precision	0.790	0.686	0.615
FScore	0.815	0.658	0.314